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Interactive learning of CG in networked virtual environments

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Abstract

Nowadays, computer graphics courses are usually taught with traditional teaching methodologies and tools, which have several limitations. In this paper, we present an online interactive computer graphics (CG) tutorial, which supports the collaborative learning of the concepts and algorithms of computer graphics in a networked virtual environment. The practical part of the tutorial consists of example programs for users to test the theoretical concepts and to obtain their own experiments. The integration of the different theoretical and practical parts of the course is realized through a common Web-based interface to the system. The main objectives are to (1) allow the users to learn and practice with the algorithms of computer graphics in a virtual environment, (2) support avatar-based collaborative learning based on avatars involving, several users connected through the Internet. Two versions of the system in Chinese and English language, respectively, have been implemented and are described in the paper.

Keywords: Computer graphics education; Java-3d; Web-based learning; Avatars; Collaborative learning

1. Introduction

Over the past decades, computer graphics education has become increasingly dependent on more powerful software tools to assist in solving more complex problems. There are many textbooks or tutorials on computer graphics [1–6]. For example, ACM SIGGRAPH provides many tutorial materials on computer graphics concept and techniques or computer graphics tools (such as OpenGL, VRML, and Direct3D).

However, topics within computer graphics (CG) still cannot be adequately presented and explored with traditional teaching methodologies and tools [7]. Therefore, an integrated approach to combine lectures, examples, programming exercises, documentation, etc., is greatly needed to enhance the learning effectiveness. In addition, we need to explore the possibility of supporting the students doing collaborative learning based on virtual reality techniques.

Teaching students to effectively understand these new algorithms or software tools in the CG field may have problems. However, software tools or algorithms are best learned by "playing with" them. Usually, the manuals for graphics software tools are often written for advanced users and can be difficult for newcomers to follow.

The professors, for teaching CG courses, often bring a notebook into the classroom, show the PowerPoint presentation, and demonstrate the program. It is difficult for the students to take notes on the algorithms that are used. Therefore, in our project we developed an interactive CG course based on the World Wide Web (WWW) and Java for teaching students to learn CG remotely and efficiently.

The rapid development of the WWW has provided unprecedented opportunities for educators to reach

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audiences of students and colleagues around the world. The WWW is a convenient and easy way to support hypermedia mechanisms that are very useful in education. This approach increases student learning efficiency by using an interactive learning environment. Web-based education is a unique learning format that allows you to attend class from the comfort of your own home. Web-based courses provide education through virtual classrooms on the Internet. Web-based education provides learners the opportunity to pursue academic programs according to their personal schedules. While weekly studies and participation are essential, students can attend class anytime of the day from anywhere. Many students find this mode of learning to be the best option when juggling time constraints with work and personal responsibilities. Many research and development proposals are focused in this aspect, and some Web-based courses are available [7–13].

Java is an object-oriented programming language that takes advantage of the strengths of the Internet [5,7]. Object-oriented programming (OOP) is a powerful way to develop software. In OOP, a computer program is considered to be a group of objects that interact with each other. The best-known feature about Java is that it can be used to create programs that execute from World Wide Web pages. These programs are called *applets*. A Java applet running on a Web page provides richer information and user interaction. Information can change in response to user input or be updated dynamically as a Web page is viewed. In CG, many algorithms will use the same techniques such as drawing lines, shading and lighting. The functions are reusable by using different user-defined classes rather than repeat the same code on different algorithms.

There are several advantages with the implementation of this interactive CG tutorial on the WWW [10]. Using a personal computer or workstation with access to the tutorial on the WWW, any user can follow the examples while browsing the tutorial. Students can get key concepts and design techniques by seeing and doing them in a similar manner. Using the mouse, the tutorial examples' source code can be downloaded without time-consuming typing and editing. Users can also explore the computer graphics algorithms written in Java and see the actual result and compare it to that of the tutorial. By using the hypertext markup language on the WWW, the tutorials are highly interconnected. Depending on user's ability, interest and available time, a user could take one of the several different paths available through the tutorials. The information contained in the tutorial is available to users when and where they are needed.

Regarding Web-based learning, two new features are integrated into such systems. One is the collaborative learning [11], the other is immersive learning using Virtual Reality (VR). For example, some studies attempt to apply the principle of constructivism and VR technologies to the curriculum of computer-aided design (CAD) by integrating network, CAD and VR into a Web-based learning environment [12].

Collaborative virtual learning environment (CVLE) plays a great role in knowledge acquisition through interactive activities among individuals. Our collaborative learning environment enables learners to explore a sharable CG world and seeks a high level of immersion. Five main features are specified as follows:

Situated knowledge: Many teaching practices implicitly assume that conceptual knowledge can be abstracted from the situations where it is learned and used. Thus, knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used [14]. The CG material from situated knowledge helps learners to establish knowledge meaning and accelerates the process of grasping abstract concepts.

Interaction with and presence of other learners: In the interactive process, tacit knowledge that cannot be codified from textbooks or lectures is transferred among the learners inside the collaborative learning environment. This gives individuals a full new impression.

Immersive learning: In virtual learning environments, each avatar represents a current learner. Avatars—well known to players of online games—are computer depictions of humans, ranging from cartoonish characters to photo-realistic representations. By enabling learners to experience and share what they see and communicate, they can develop a deeper understanding of highly complex concepts.

Communication in the learning process: Communication is also regarded as a social interaction. It is an important tool for learners to exchange ideas, and share important information. Through communication, each learner's thoughts, experiences, knowledge, resources, can be shared by the whole learning group. Two types of communication tools is implemented, one using a text-based chatting room and another that takes advantage of a bulletin board showing information.

Collaboration in the learning process: Collaboration is a method by which small groups of students incorporate a co-operative task structure, a co-operative incentive structure and a collaborative motive to produce collaborative behavior [15,21]. Through group discussion or group working, learners can learn not only from the learning environment, but also from each other.

In this paper, we will present our work on interactive learning of CG algorithms in virtual environment connected through the Internet. The remainder of the paper is organized as follows. In Section 2, we will discuss the design methodologies. In Section 3, the interactive learning aspects and related examples are given in detail. In Section 4, the collaborative and immersive features and implemented techniques are discussed. In Section 5, we discuss about the user experiences to our prototype system. Conclusions and future work are presented in Section 6.

2. Design methodologies

2.1. Functional requirement

It is expected that the system should be able to provide four main functions:

(1) *Computer graphics tutorials*: The system can be used as an online tutorial on computer graphics, providing related materials on Internet. To make the web page more attractive and practical, multimedia such as image, video and audio play an important role on the Web-based system. In addition, some concepts of CG are often difficult to understand through textual descriptions. An animated example can help the user to understand better.
(2) *Computer graphics examples using Java*: To help the students to learn computer graphics more efficiently , the system need to provide some examples to illustrate the concept, and algorithms in computer graphics. The learners can interact with the system. For example, users can specify the parameters such as line attributes and color of the object and perform the function interactively. Users can understand more deeply using the interactive online examples.
(3) *A download area for source codes*: To train the programming ability on graphics rendering, the system can provide the source code for students' experiments. After having understood the concepts of the algorithms and having tried the examples, the users may want to learn about the details of the source code of the examples. Providing the downloadable source code allows the users not only to learn the conceptual part, but also the implementation part.
(4) *Supporting collaborations*: By using VR techniques, the system can support a certain degree of immersion, and the collaboration is enhanced with virtual avatars representing different users in the networked virtual environment.
(5) *Portability and* WWW *connection*: Portability should be another consideration in addition to internationalization. The tutorial is platform independent since it is written in HTML and Java code which are portable. The new or updated version of the examples will be changed from time to time. So, it should allow the user to download using a connection to WWW.

2.2. System design

Electronic textbook on CG is a multimedia-based system. The whole design concept follows an easy-to-use philosophy. Because one of the purposes of the system is to provide an easy learning environment on CG, the web environment is chosen for the whole system. Users can learn CG when they want just a click on the web page.

2.2.1. System design considerations

User characteristics: The system is mainly designed for students. They may have little or even no background knowledge on CG and little computer knowledge. Those factors are considered to affect how they interact with the system. In order to provide a suitable, user-friendly system and satisfy the needs of the user, an analysis of user characteristics is needed before designing the system.

Attracting users: In order to guarantee the success of the tutorial, the materials and the method of presentation must be able to attract the users. The sequence of the presentation should be carefully planned. To achieve this, the tutorial should employ multimedia technology. It includes playing sound, video and animation. These attract the users and it can help them to keep visiting this page. From the user's point of view, the system should be simple and easy to use. Users just click on what topics and examples they want. By using VR techniques, the system can support immersion to a certain degree.

Interactive learning: Most CG tutorial web sites are only presented in plain text form. They are usually organized in a way that includes few graphics. The multimedia information is usually only presented in CD-ROM format. The system should provide an interactive environment to the users. This can be accomplished by providing interactive information and hypermedia support. In interactive information systems, users can receive an immediate feedback on their selection. During the content presentation, people can click the links to demonstrate the examples or click the start button to run the Flash movie. In our system, the users can interact by setting parameters for different algorithms. The users can also interact with other users who are studying the courses.

2.2.2. System architecture

Users can directly click on any example. The system architecture is transparent to the users which means users will not need to know how the program actually works. The architecture of the underlying interactive CG learning system is shown in Fig. 1. The history of the system can be retrieved back to 1999. In the first version, the system was a Web-based interactive learning system. Two versions are now implemented: one in Chinese (Zhejiang University) and one in English (The Hong Kong Polytechnic University[1]). Furthermore, in 2003 we extended the system into virtual environments, supporting immersive and collaborative learning, in

[1]The work is done when the first author working in The Hong Kong Polytechnic University as a visiting professor.

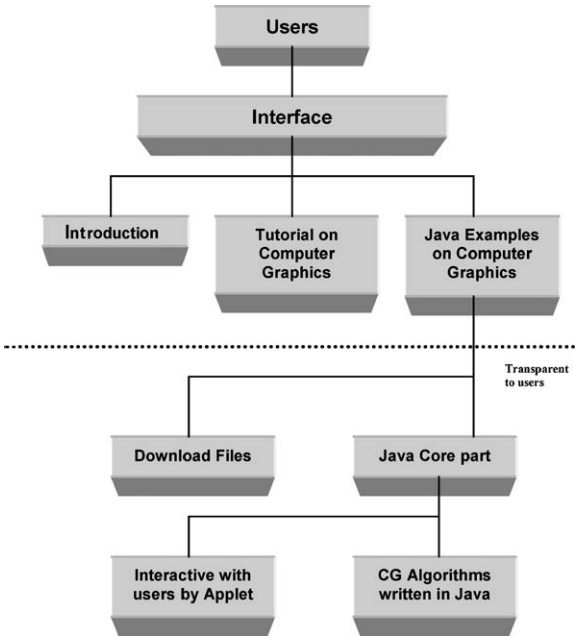


Fig. 1. The system architecture of the early version.

cooperation with the Institute of VR and Multimedia, HZIEE.

3. Interactive learning environments

In this section, we will describe the interactive learning aspects supported by the earlier version of our system. In Section 4, we will focus on other features in the new version.

3.1. User interface design

This online tutorial runs with a browser such as Netscape or Internet Explorer. The resolution is designed to be 1024×768. After the selection of the subtopic, the content page will be displayed on the right frame. Fig. 2(a) is a snapshot of our English version of the interactive CG textbook. Fig. 2(b) is a snapshot of our Chinese version of the interactive CG textbook.

3.2. Flash and animation illustrating CG concepts

We use Flash and some animation clips to illustrate some basic concepts of CG. Fig. 3(a) is the illustration of the three basic geometric operations (scale/rotate/transform), while Fig. 3(b) is the interactive illustration of the effect of the color model.

3.3. Java examples

In this sub-section, we will give some examples, which are generated from the two experimental systems (the Chinese and English version).

3.3.1. Example 1: Polygon clipping

In this example, the applet will show the user how the polygon is being clipped (see Fig. 4). Initially, there is only a rectangle at the center of the applet. On the bottom of the applet, there is a button call "Finish". First, the user should click on the applet. The applet program will record the position where the user clicks and shows a small rectangle on it. The user should click at least three points to form a polygon. Then the user should click the "Finish" button to finish the process. After clicking the button, the applet will draw the polygon with lines and fill the clipped polygon in red color.

3.3.2. Example 2: Bezier surface

In this example, the applet will show the difference between the surface before and after applying the Bezier surface (see Fig. 5). The applet will first generate the original surface. Then it will generate a Bezier surface with the point relevance to the original one. The Bezier surface will be generated and displayed in the right-hand side. The "Random" button at the bottom of the applet allows the user to generate a new surface by randomly selecting the point value. The new Bezier surface will then be displayed.

3.3.3. Example 3: Rendering algorithms

In this example (see Fig. 6), the applet will show the difference between the results of two kinds of rendering algorithms. In the left window, the result of the normal rendering algorithm is shown: while in the right, the result of the ray-tracing algorithm is displayed. The users can view the source codes of the two rendering algorithms if necessary.

4. Collaborative virtual learning environment

In this section, we will discuss the collaborative aspects of our new version. Our CVLE implementation uses a client/server architecture. The VRML [16] browser plug-in is used to render the 3D scene using Blaxxun Contact plugin [17]. Designers can also change to other plug-in, such as CortonVRML4.0, Cosmo-player or Java applets displaying subsets of VRML97 such as blaxxun3d, IBM Hypermedia, Cortona Jet, and Shoud3D. The Java graphic interface is a human–machine interface designed according to a constructivism learning tool kit, which includes personal information,

Fig. 2. User interface: (a) English version. (b) Chinese version.

upload resource, course maker, course modifier, learning course, 3D chat room, and shared whiteboard. The communication tool supports synchronized message delivering. The Event Dispatcher dispatches all the request events to server (such as the request for login, the request to download a resource, and the request for synchronization) or gets events from server (such as get user information, get resource, etc.) [19]. The system protocol is TCP/IP based for supporting communications between clients and server.

A reconstruction of the CG material introduced in Section 3 is accomplished by embedding a text introduction, a Flash movie, virtual experiments, and interactive algorithms in the sharable world. In the environment, we build several houses to be the material house. Each house is divided into two rooms, one for the course material learning and one for virtual experiments. Four different showcases are supported. A narrative text is converted to a sequence of images. Animation is used to clearly show the results of the instruction resource

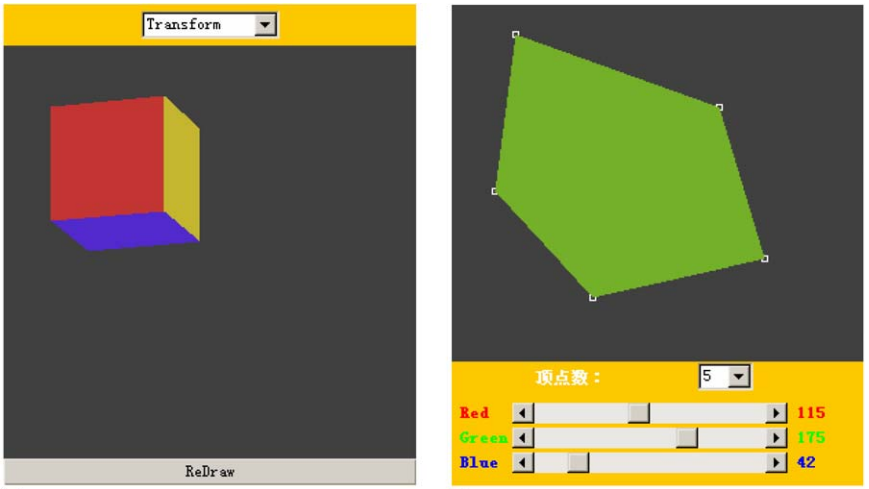


Fig. 3. Flash and animation: (a) Illustrating scale/rotate/transform. (b) Interactive illustrating color model.

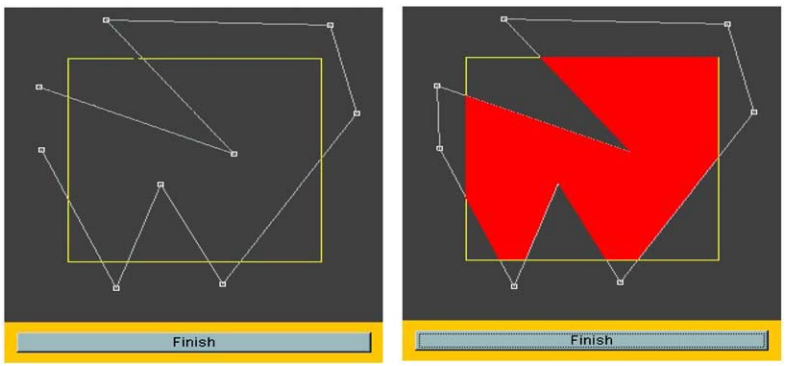


Fig. 4. Example of polygon clipping.

that can also be used to substitute page rolling. Flash animation in VRML is supported using RealPlayer software (MOVIETEXTURE nodes). This also helps designers to control the process of playing animations. Virtual experiments in cooperation among several learners provide an opportunity to experience new CG algorithm features in 3D.

Practical research on education shows that individual learning processes and multi-learning processes are two very relevant ways to acquire knowledge. The former emphasizes the initiative of learning. The latter emphasizes both the initiative and also a passive way of learning [18,20]. Individual learning requires rich course material representation while multi-learning needs rich communication methods in multi-user environments. CVLE provides experiments in multi-learner examples. Fig. 7 shows two users controlling their avatars in a virtual CG world.

In this virtual learning environment, we represent each user with an avatar. We therefore can combine the best parts of both face-to-face training and computer-based learning. Like other computer-based learning/training programs, those using avatars can be cheaper and more efficient than human trainers, and deliver a more consistent message. At the same time, they offer an almost human touch that may help to reinforce that message.

5. User experiences

Web-based learning environment has shown its remarkable usage and advantages in distance learning. Using a network-supported computer, the student can learn anywhere, at any time. This paper presents an approach for building a convenient, immersive, sharable CG virtual world for collaborative learning. The attractive interface and the CG algorithm source code implemented using Java is accessible through Internet,

which provides an easy access for learners. Results show that students are much likely to log in the CVLE world to experience the proposed activities rather than just reading the web-page introduction.

However, based on our experiment results, we found that learning effectiveness was not as good as we expected, and sometimes, it is even surprising to us. Students learning CG courses through the simple web pages and Java examples are grasping the concepts well, while students in the virtual CG world are not that good. Our explanation for this fact is that in the 3D world, there are many things to distract a learner from his learning, such as chatting and walking.

Some comments from the users are (1) Add CG teachers as virtual avatars. The teachers need to log into the system at specified time period to answer the questions online, or discuss online. (2) Add some games related to graphics concepts into the prototyped system. (3) Customize the avatars. For examples, some users would like to have their face to be mapped to the 3D avatars. (4) Program code should be in C or C++.

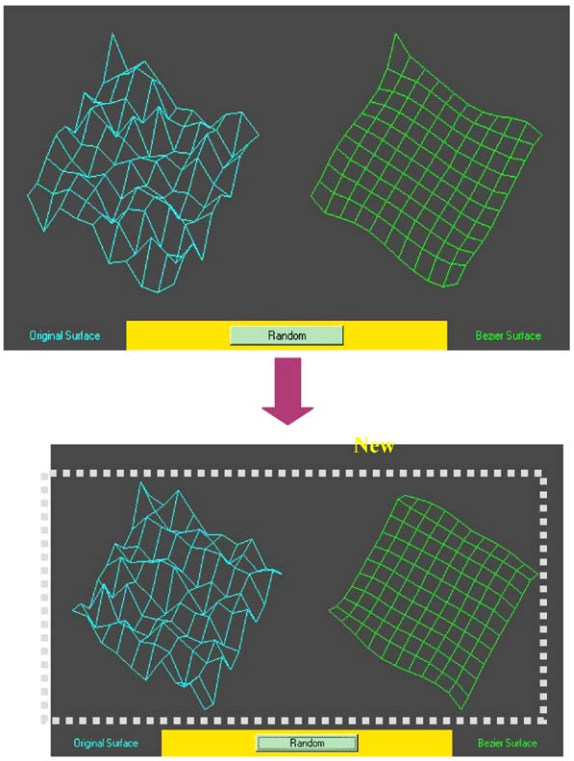
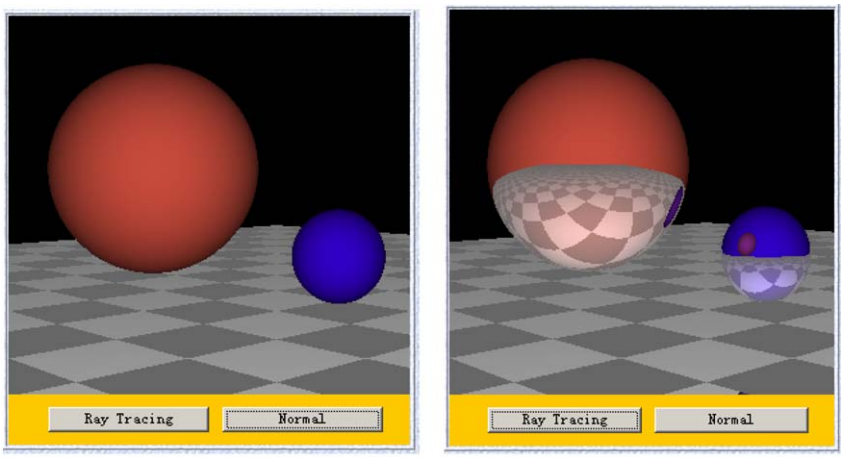


Fig. 5. Example of bezier surface.

6. Conclusions

In this paper, we presented an online interactive CG tutorial, which supports the collaborative learning concepts and algorithms of computer graphics in a networked virtual environment. Future work includes the following aspects:

- How to elaborate the 3D course material.
  Concepts presented in a 3D way should not loose their original meaning and must be easy for learners' access.
- How to limit learners unnecessary activity in order to reinforce learning effectiveness.
  In CVLE topology, a new module should be added to limit learners' activity. For example, learners need first to correctly answer related CG questions and only then they can chat with others.



(a) (b)

Fig. 6. The results of two kinds of rendering algorithms: (a) Normal rendering algorithm. (b) Ray-tracing algorithm.

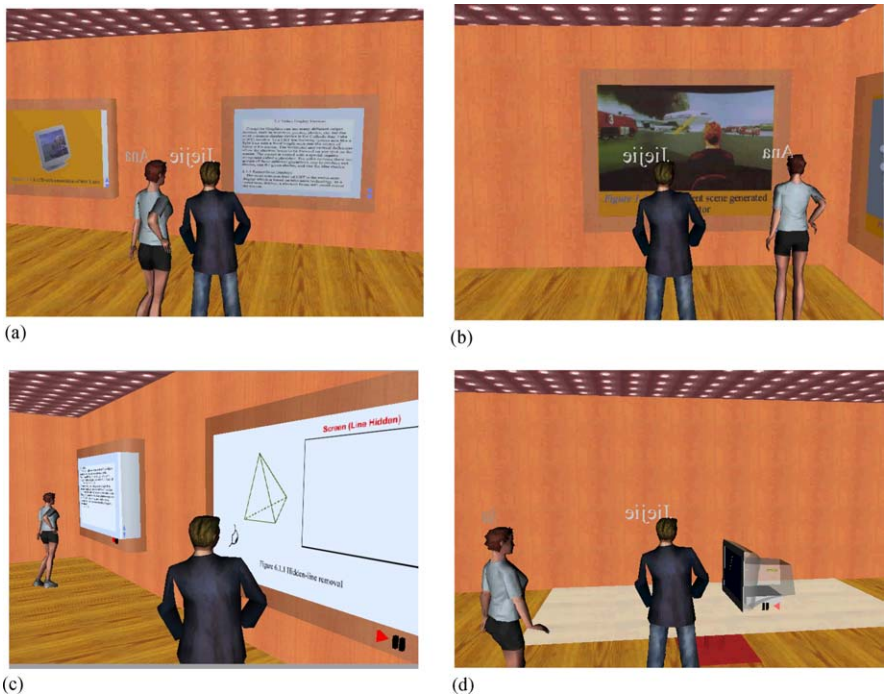


Fig. 7. Screen shots for collaborative learning activity: (a) Reading text introduction together. (b) Discussing car drive simulation software. (c) One avatar is reading introduction, another is watching the flash animation. (d) The boy is introducing CRT raster theory to the girl controlled by two learners.

- How to improve synchronization in virtual experiments.

Our results show that all learners are very excited when they can do experiments together. Synchronization is an issue left as further research in CVLE.

Virtual sound is another aspect considered for future developments of the system.

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